



## Application Note

### RS-485 to Plastic Optical Fiber Converter



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# Introduction

This application note describes how Firecomms RedLink® fiber optic transceivers offer many advantages when used in industrial serial RS-485 based networks. Industrial environments pose many challenges to communications engineers. Mission critical, high voltage equipment must be reliably controlled at high temperatures in areas with high amounts of electrical noise.

Plastic Fiber Optical Links can be used to provide reliable communication links, galvanic isolation, common mode rejection and electromagnetic interference immunity whilst being cost-efficient. Firecomms RedLink® components are “Drop-in” compatible with the versatile link family of transmitter and receivers and offer a number of distinct advantages.

## RS-485

RS-485, also known as TIA-485(-A), EIA-485, is a standard which defines the electrical characteristics of drivers and receivers for use in serial communications systems. Electrical signalling is balanced and multi point systems are supported. The standard is jointly published by the Telecommunications Industry Association and Electronic Industries Alliance (TIA/EIA). Digital communications networks implementing the standard can be used effectively over long distances and in electrically noisy environments. Multiple receivers may be connected to such a network in a linear, multi drop bus. These characteristics make RS-485 useful in industrial control systems and similar applications.

## POF - Plastic Optical Fiber

Plastic Optic Fiber is a robust industrial fiber that provides simple data links between machines and their controllers. The fiber has a long and successful history in the high-power industry, locomotive and automotive applications as well as in medical devices. It has three major attractions; it provides the maximum possible RF isolation between devices as no electrical signal can travel across the plastic fiber, It is easily field terminated which is important for plant installation and maintenance, It is robust and can be routed into a tight bend radius as well as co-habiting with high voltage conductors in cable trays.

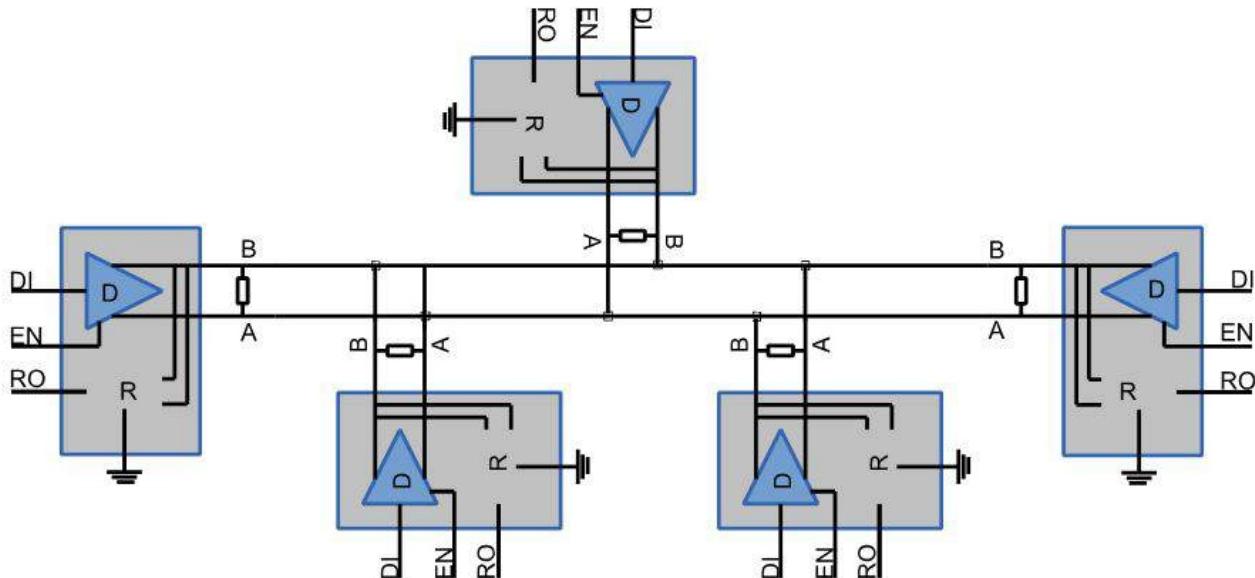
## Plastic Optical Fiber Transceivers

Plastic Optic Fiber Transceivers are small robust industrial fiber transceivers that facilitate simple cable plug assemblies. They have a small form factor and very simple digital TTL interfaces. They are ideal for use with low speed industrial data bus links such as RS-232 and RS-485.

# Industrial Communications and RS-485

RS-485 is used as the physical layer for many interface standards including Profibus, Bitbus, ARCNET, InterBus, LON and Modbus. The RS-485 standard was developed by the Electronic Industries Association (EIA) and the Telecommunications Industry Association (TIA). The "RS" (Recommended Standard) was a prefix, used by the EIA and is still in common use.

RS-485 specifies the electrical properties and characteristics. It does not specify the communication protocol to be used. RS-485 is a multi-drop, bidirectional, balanced transmission line standard.



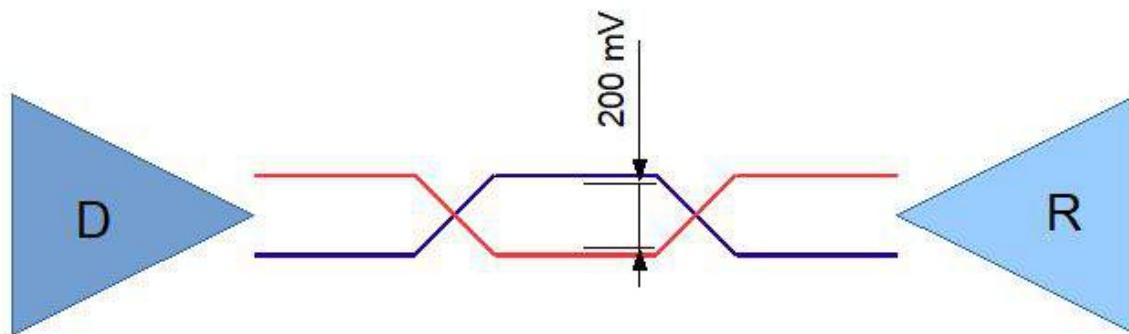
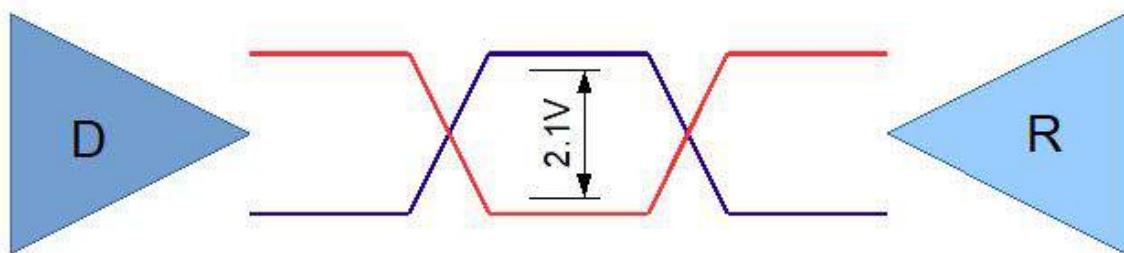
RS-485 supports inexpensive local networks and multi-drop communications links, using the same differential signalling over twisted pair as RS-422. It is generally accepted that RS-485 can be used with data rates up to 10 Mbit/s or, at lower speeds, distances up to 1,200 m.

In contrast to RS-422, which has a driver circuit that cannot be switched off, RS-485 drivers use three-state logic allowing individual transmitters to be deactivated. This allows RS-485 to implement linear bus topologies using only two wires. The equipment located along a set of RS-485 wires are interchangeably called nodes, stations or devices. The recommended arrangement of the wires is as a connected series of point-to-point

(multi-dropped) nodes, i.e. a line or bus, not a star, ring, or multiply connected network. Star and ring topologies are not recommended because of signal reflections or excessively low or high termination impedance. If a star configuration is unavoidable, special RS-485 repeaters are available which bidirectionally listen for data on each span and then retransmit the data onto all other spans.

Biassing and termination values are not specified in the RS-485 standard. Ideally, the two ends of the cable will have a termination resistor connected across the two wires. Without termination resistors, signal reflections off the unterminated end of the cable can cause data corruption. Termination resistors also reduce electrical noise sensitivity due to the lower impedance. The value of each termination resistor should be equal to the cable characteristic impedance (typically, 120 ohms for twisted pairs). The termination also includes pull-up and pull-down resistors to establish fail-safe bias for each data wire for the case when the lines are not being driven by any device. This way, the lines will be biased to known voltages and nodes will not interpret the noise from undriven lines as actual data; without biasing resistors, the data lines float in such a way that electrical noise sensitivity is greatest when all device stations are silent or unpowered.

The maximum and minimum line voltage swings of the RS-485 electrical signals are illustrated below.



# Half Duplex Links (3 wire operation)

Often in a master-slave arrangement when one device, the master, initiates all communication activity, the master device itself provides the bias and not the slave devices. In this configuration, the master device is typically centrally located along the set of RS-485 wires, with two slave devices located at the physical end of the wires providing termination. The master device itself could provide termination if it were located at a physical end of the wires, but that is generally regarded as a bad topology design as the master operates optimally when located at a halfway point between the slave devices, thereby maximizing signal strength and therefore line distance and speed. Applying the bias at multiple node locations could possibly cause a violation of the RS-485 specification and cause communications to malfunction.

# Full Duplex Links (4 wire operation)

RS-485, like RS-422, can be made full-duplex by using four wires. Since RS-485 is a multi-point specification, however, this is not necessary in many cases. RS-485 and RS-422 can inter-operate with certain restrictions.

Converters between RS-485 and other formats are available to allow a personal

computer to communicate with remote devices. By using "Repeaters" and "Multi-Repeaters" very large RS-485 networks can be formed. TSB-89A, The Application Guidelines for TIA/EIA-485-A has one diagram called "Star Configuration. Not recommended." Hub/Star systems (with "Multi-Repeaters") allow for very maintainable systems, without violating any of the RS-485 specifications. Repeaters can also be used to extend the distance or number of nodes on a network.

## Fiber and RS-485

The 3 and 4 wire interfaces of RS-485 are not a natural fit to a fiber optic transceiver. Furthermore, the electrical signals and termination resistances are not directly compatible. As a result, to implement RS-485 over fiber it is important to use the dedicated RS-485 transceivers which convert the RS-485 bus to a standard TTL logic scheme which is then 100% compatible with the fiber optic transceivers. Options are available supporting both full duplex and half duplex operation. In this application note we use Maxim RS-485 transceivers to make the interface conversion. These are just examples and similar devices are available from a number of manufacturers.

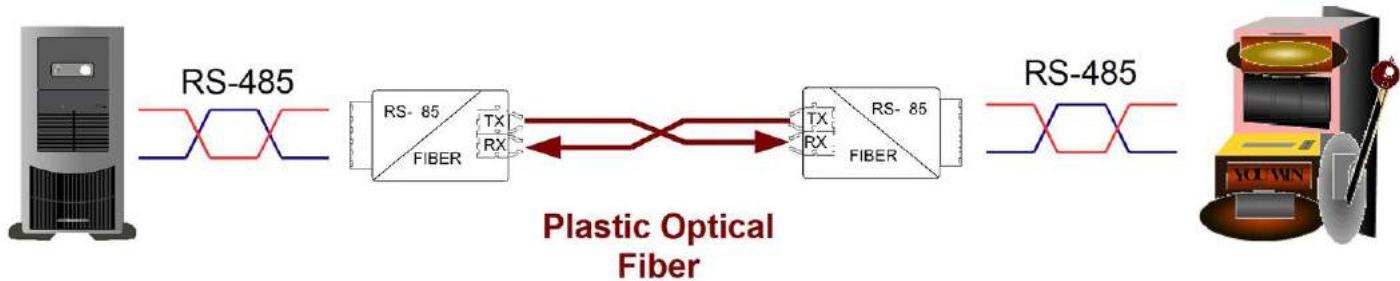
# An important note on Data Rate

The Data Rate on many RS-485 links is often below 1 Mb. This is especially true for longer links. However, when implementing a link with fiber optic transceivers it is a mistake to select transceivers matched to the low data rate. The electrical rise and fall times of the RS-485 are key parameters to ensure error-free communication. The rise and fall times of low speed fiber optic transceivers are often longer than the expected electrical pulse and as a result the RS-485 node can mistake a slow rising optical signal as a digital zero instead of a digital one. Therefore, when selecting optical transceivers to operate with RS-485 it is important to select a

fiber optic receiver with a data rate of 10 MBd or above, to ensure the electrical signal from the optical link going back to the RS-485 input DI has fast rising and falling edges.

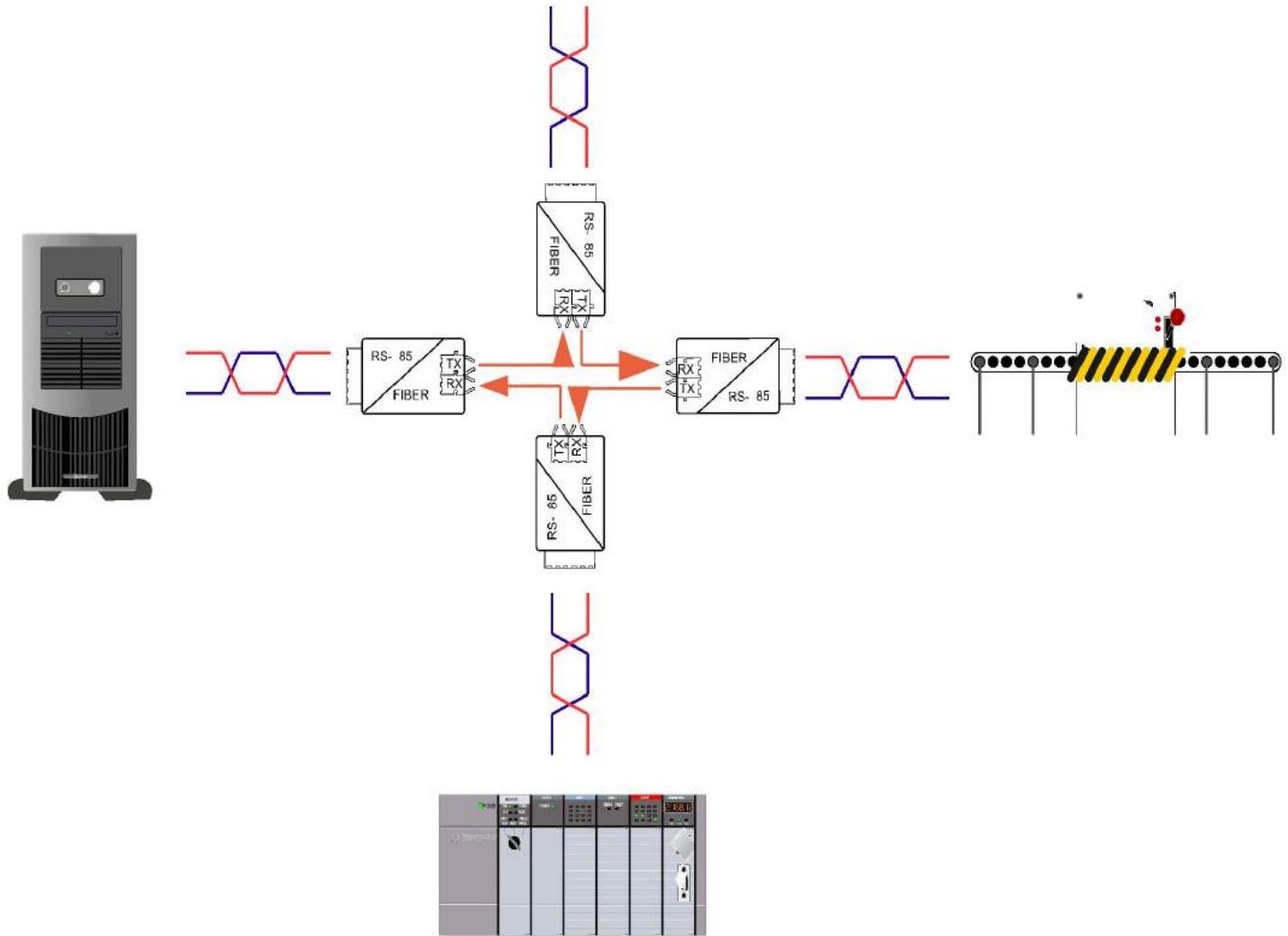


## RS-485 Point to Point Link



- Building to building
- Bus segmentation
- Optical isolation

# Multi-Drop Ring



## Galvanic Isolation and Electromagnetic Interference (EMI/EMC)

Plastic fiber optical links inherently provides excellent galvanic isolation easily exceeding IEC standards with short links.

Plastic optical fiber is immune to EMI. Fiber can be run alongside power cabling or in close proximity to electrically noisy equipment without noise pickup or data corruption.

POF does not radiate emit EMI and can be routed alongside sensitive, copper-based communications and in applications where security is of the utmost importance. Finally, the RedLink® transceivers can be used to reject, potentially dangerous common mode potentials for example when building to building communications are needed or in areas where lightning can be an issue.

# The POF Link

The plastic optic fiber link consists of a TTL driver circuit that takes the RO signal from the RS-485 transceiver and uses it to drive an LED or RCLED. The light signal from the LED is visible red or green light and this is coupled into a 1 mm core plastic optic fiber. The transceiver uses a very simple plug connector which is easily terminated with common hand tools. No specialist equipment or training is required. At the far end of the fiber the receiver takes the optical signal and converts it back to a TTL compatible electrical signal. As already presented, the speed of the rising and falling edges of this signal are critical to correct interpretation of the transmission signal.

An important point to note is that the light logic on the fiber is inverted. "Light on" represents a digital zero (data low) and "light off" is equal to a digital one (data high). The reason for this is that this inverted logic configuration facilitates easy installation and maintenance of the fiber optic link. With this inverted logic when a fiber is disconnected from the link the light is on and therefore the optical power level can easily be measured with an optical power meter. When no data is being transferred the RO signal will be low and therefore the light will be set to high which is on. As the light is in the visible spectrum this allows technicians to quickly and easily diagnose a broken or damaged fiber or a failure at the transmitting side of the link.

## Optical Budget for RS-485 Link over POF

### RED RCLED @ 650 nm

Transmitter: Using the FT10MxLR (where x = H for Horizontal, V for Vertical and W for 30' tilted) we have the following optical power range.

If the drive current is = 30 mA, then Optical power = min -3 dBm, typical +2 dBm.

Receiver: We select the inverting FR10DxIR for simplicity in the application circuit.

It has a minimum optical power sensitivity of – 22 dBm.

Optical budget for standard 1 mm core step index POF with NA = 0.5

- Tx minimum optical power coupled into POF = -3 dBm
- RX minimum optical power sensitivity = -22 dBm
- Power available in the fiber = 19 dB
- Power loss per meter at 650 nm in POF = 0.19 dB/m
- Maximum Link distance for all temperature conditions = 100 m @ 650 nm

# GREEN LED @ 530 nm

Transmitter: Using the FT01MxNG we have the following optical power range.

If the drive current is = 20 mA, then Optical power = min -2 dBm, typical +1 dBm.

Receiver: We select the inverting FR05DxIR for simplicity in the application circuit. It has a minimum optical power sensitivity of - 22 dBm.

## Optical budget for standard 1 mm core step index POF with NA = 0.5

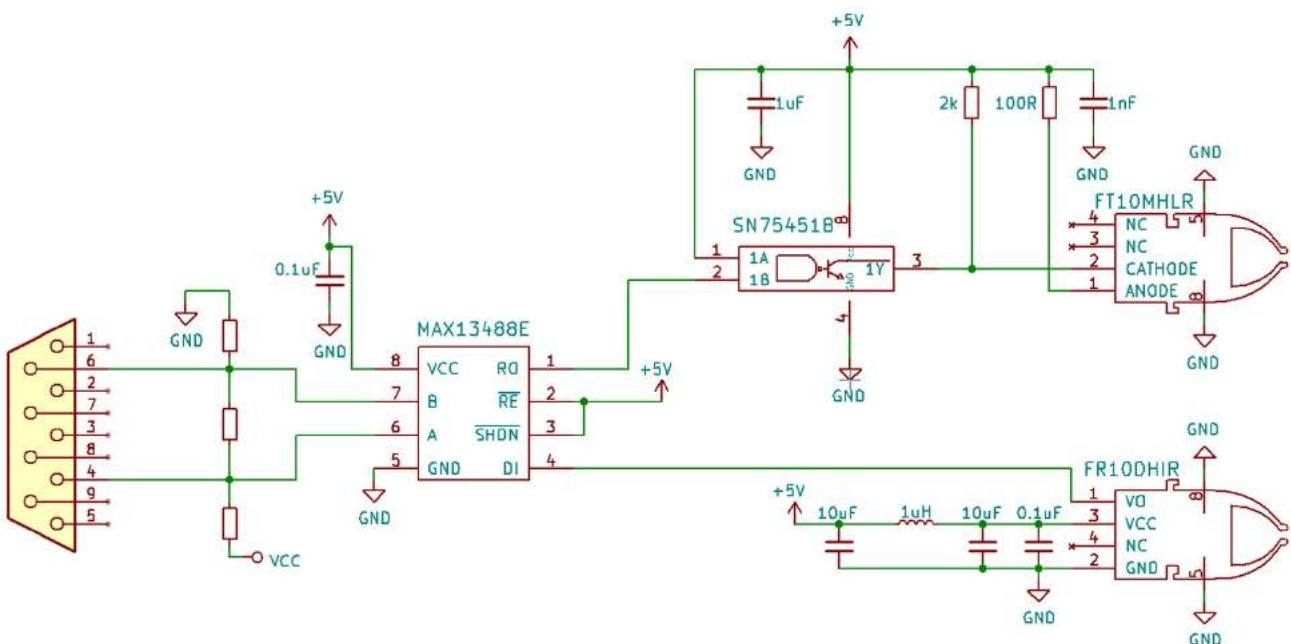
- Tx minimum optical power coupled into POF = -2 dBm
  - RX minimum optical power sensitivity = -22 dBm
  - Power available in the fiber = 20 dB
  - Power loss per meter at 530 nm in POF = 0.0647 dB/m
  - Maximum Link distance for all temperature conditions = 309 m @ 530 nm

# Schematics

NOTE: Both driver circuits give the required optical power using a 100 Ohm current limiting resistor (R1).

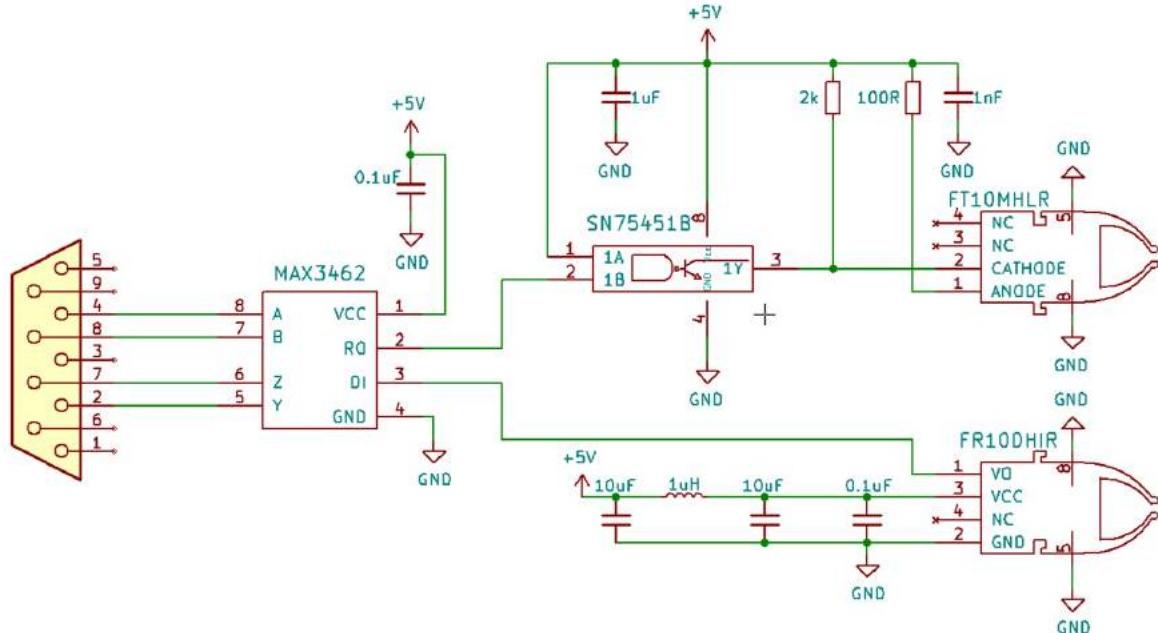
## HALF DUPLEX WITH RED Tx LED

This schematic shows how FR10DHNR and FT10MHLR can be used to interface with RS-485 half-duplex networks. It implements via the Maxim MAX13488E automatic direction control.



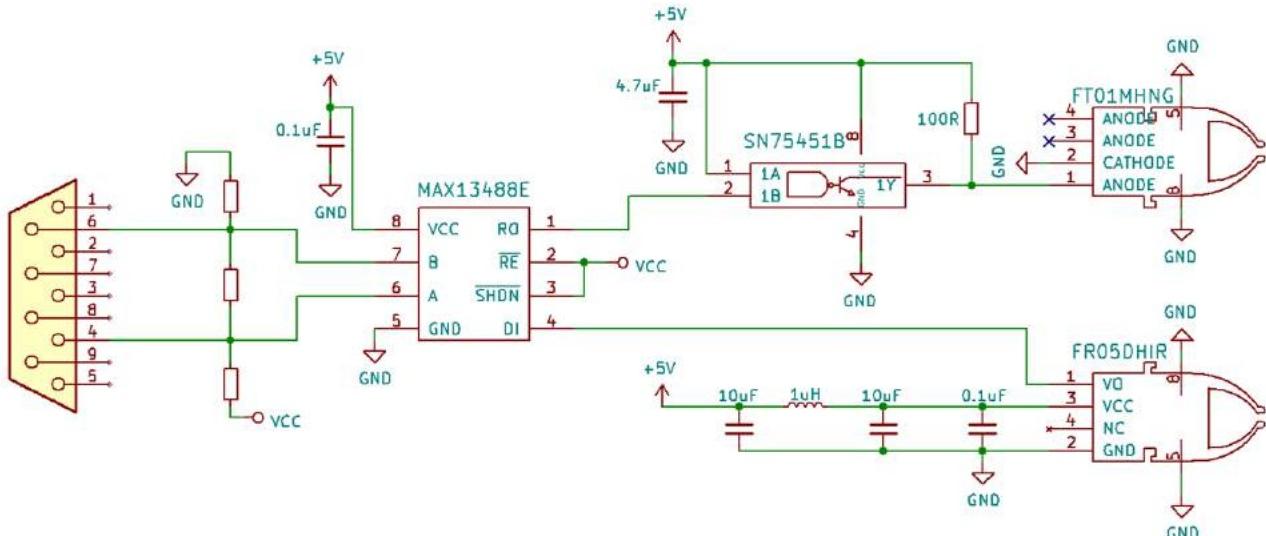
## FULL DUPLEX WITH RED Tx LED

This schematic shows a circuit that can be used to interface Firecomms transceivers with a 4-wire based RS-485 data bus. The MAX3462 provides signal conditioning.



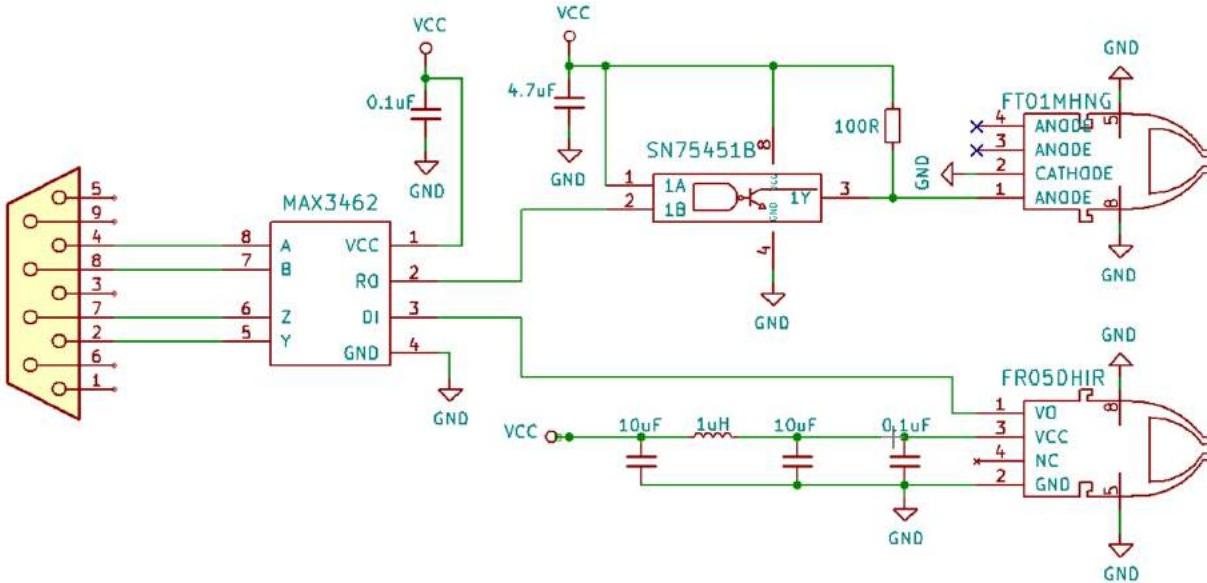
## HALF DUPLEX WITH GREEN Tx LED

This schematic shows how FR05DHIR and FT01MHNG can be used to interface with RS-485 half-duplex networks. It implements via the Maxim MAX13488E automatic direction control.



## FULL DUPLEX WITH GREEN Tx LED

This schematic shows a circuit that can be used to interface Firecomms transceivers with a 4-wire based RS-485 data bus. The MAX3462 provides signal conditioning



## Conclusion

The application circuits presented in this document may be used to implement a fiber-based RS-485 networks. The purpose of these networks could be to provide secure, reliable communications which are galvanically isolated, noise immune and reject common mode noise and voltages.

The RedLink® connectors bring options for visible Red LED (650 nm) and Green LED (530 nm). The transceivers can be paired with both Plastic Optic Fiber and with Hard Clad Silica fiber.

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